Synopsis

Formulation of Blended Vegetable Oils and Investigation of their Fatty Acid Profile in Cooked Products

By

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In partial fulfillment of the Degree of Doctor of Philosophy in

Food Service Management and Dietetics

SEPTEMBER 2024

ABSTRACT

Dietary variations play a crucial role in determining a country's health and well–being. The onset of diet-related disorders is closely associated with food intake, specially oil intake. Blending of oils has become a more financially successful technique to improve oxidative stability and nutrient profile of oil by maintaining a balanced fatty acid profile in recent years. Thus, blending oils to create an alternative cooking medium with desired health advantages is the need of the day. The study was carried out in four phases. In Phase I, a survey on household consumption of dietary fat was done among 196 households at Coimbatore and a market survey on the availability of blended vegetable oil was carried out in eight outlets. In Phase II, the formulation of six blended vegetable oils (BOGN-I, BOGO-II, BOSF-III, BOSFO-IV, BOFO-V, BOEP-VI) using groundnut, gingelly, sunflower, safflower, and flaxseed oil was done and their physical, chemical and sensory attributes were tested using standard procedure. In Phase III, the fatty acids profile of formulated blended vegetable oil was analyzed using a gas Chromatography - Flame Ionization Detector). In Phase IV, the absorption of oil and fatty acids profile of selected recipes cooked (Deep fat frying - vadai, Pan frying - chapatti, Sautéing - potato poriyal) using formulated blended vegetable oils were analyzed (GC-FID). Forty eight percent of households belonged to an upper lower socio-economic group. The consumption of groundnut oil was found to be maximum (108 ml) followed by sunflower oil (87 ml). Blending of more than three oils was not observed. The physical properties of all the six formulated blended vegetable oils were in par with stand-alone oil. The chemical properties of the blended vegetable oils reported better oxidative stability than stand-alone oils. The sensory attributes of all the blended vegetable oils were in par with the stand-alone oils and hence can serve as an alternate cooking medium. The blended oils BOSF-III and BOSFO-IV reported the least oil absorption in cooked products and were found to be low in saturated fats, and high in MUFA and PUFA. Hence they can be recommended as healthier oils compared to stand-alone oil.

Introduction

In Indian cuisine, oil plays an important role, not just for its role in adding flavour but also in providing vital fatty acids, vitamins, and energy. They are important for both culinary and nutritional purposes. Fat plays a major role in human health and it contains saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, and triglycerides. The essential fatty acids are not synthesized and can be obtained only from our diet. Irrespective of their origin from animal or plant sources fats and oils have a major role to play in the pathogenicity and etiology of both communicable and non-communicable diseases (Onishi *et al*., 2020).

There is a growing global interest in exploring the potential health benefits of edible fats and oils, particularly for chronic diseases, given the close connection between diet and inflammatory responses. Edible oils, derived from plant-based sources such as oilseeds, are rich in antioxidants and phenolic compounds, making them important components of our daily diet. The combination of phenolic compounds and vitamins present in edible oils may help to prevent chronic diseases by exerting anti-inflammatory, antioxidant, neuroprotective, and immune modulatory effects (Mazzocchi *et al*., 2021).

Many oils lack sufficient amounts of essential fatty acids, which are vital for regulating lipid metabolism. As rightly pointed out by Balta *et al*., (2021), the balance between omega-6 (n-6) and omega-3 (n-3) fatty acids is critical: an imbalance can contribute to various health issues, including diabetes, atherosclerosis, obesity, high blood pressure, and cancer

Healthcare professionals claim, that a single oil would not be sufficient to provide the ideal blend of fatty acids in triglycerol (TGA) of oils and fats. Blending oil can lower blood levels of triglycerol and cholesterol in addition to providing a balanced fatty acids profile (Li et al., 2020). As rightly pointed out by Dhyani et al., (2018) blending is a straightforward, practical, and cost-effective strategy to improve the physiochemical and nutritional qualities of the oil, this claims stand good as many studies have shown that using the right oil mixes can lower cholesterol and triglycerol levels in the blood and liver (Vergallo., 2020) besides improving their functional properties.

Research Gap

- Literature survey showed blending of only two oils
- Majority of blends used palm oil and rice bran oil
- Blending of three oils was less attempted and blending with more than three oils was not attempted
- Though FSSAI and ICMR have recommended flaxseed oil as a cooking medium in 2021, to the best of the knowledge of the investigator the usage of this polyunsaturated fatty acids-rich oil in blending has not yet been attempted
- Also, studies on the fatty acids profile of cooked foods, particularly for different types of frying using blended vegetable oils are very limited.

Objectives of the Study

Primary Objective

- The primary objective of the study is to **"Formulate blended vegetable oils and investigate their fatty acid profile in cooked products."**

Secondary objectives

The secondary objectives of the study is to

- study the consumption of fats and oils in selected households of Coimbatore
- survey the market availability of blended vegetable oils
- formulate blended vegetable oils and assess their quality attributes
- analyze the fatty acids profile of the formulated blended vegetable oils and
- to investigate the fatty acids profile of products cooked using the formulated blended vegetable oils.

Hypotheses

- Hypothesis $_{01}$ There is no significant difference in the refractive index of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis $_{02}$ There is no significant difference in the density of the formulated blended vegetable oils with that of stand-alone oils

- Hypothesis $_{03}$There is no significant difference in the viscosity of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis $_{04}$There is no significant difference in the organoleptic acceptability level of the formulated blended vegetable oils with that of stand-alone oils.
- Hypothesis $_{05}$ There is no significant difference in the peroxide value of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis $_{06}$There is no significant difference in the iodine value of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis $_{07}$ There is no significant difference in the saponification value of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis $_{08}$ There is no significant difference in the acid value of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis $_{09}$ There is no significant difference in the free fatty acid profile of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis $_{010}$There is no significant difference in the fatty acid profile of the cooked products prepared using the formulated blended vegetable oils with that of stand-alone oils

Methodology

The study was conducted in four phases:

Phase I: A Survey on Consumption of Fats and Oils and Market Availability of Blended Oils

A) Survey on Household Consumption of Fats and Oils

Coimbatore City was selected for the conduct of the study through purposive sampling. By applying the Cochran's formula ($N = z^2(pq)e^2$), a total of 272 households were selected through convenience **s**ampling. As the study was conducted during Covid pandemic only 196 households were surveyed. Female members of the selected household were selected as respondents. Pre-tested interview schedule was used to collect background data namely, age, sex, education, income, and occupational status. A modified Kuppuswamy scale (2018) was used to study the socioeconomic status of the selected household. The dietary pattern of the selected household namely the types of diet consumed, meal pattern, preference for particular food, and the different methods of cooking were collected from the female subjects, with the help of

an interview schedule. Information on the quantum and frequency of consumption of fats and oils was elicited through a pretested and a validated modified food frequency schedule. The average quantum of consumption of fats and oils per household and per person was collected using the inventory method.

B) Market Survey on Availability of Blended Vegetable Oils

A market survey was conducted at eight retail shops comprising two shops (one commercial and one wholesale) from four geographical regions of Coimbatore. The availability of types, brands, and quantities of stand-alone oil and blended vegetable oils was studied with the help of an observational checklist.

Phase II: Formulation of Blended Vegetable Oils and their Quality Analysis

Traditionally cold-pressed groundnut, gingelly, sunflower, safflower, and flaxseed oils were procured from a cold-pressed oil vendor. A total of six blended vegetable oils were formulated as given in (Plate I). The groundnut, gingelly, sunflower, safflower, and flaxseed oil were taken as stand-alone oil for comparison.

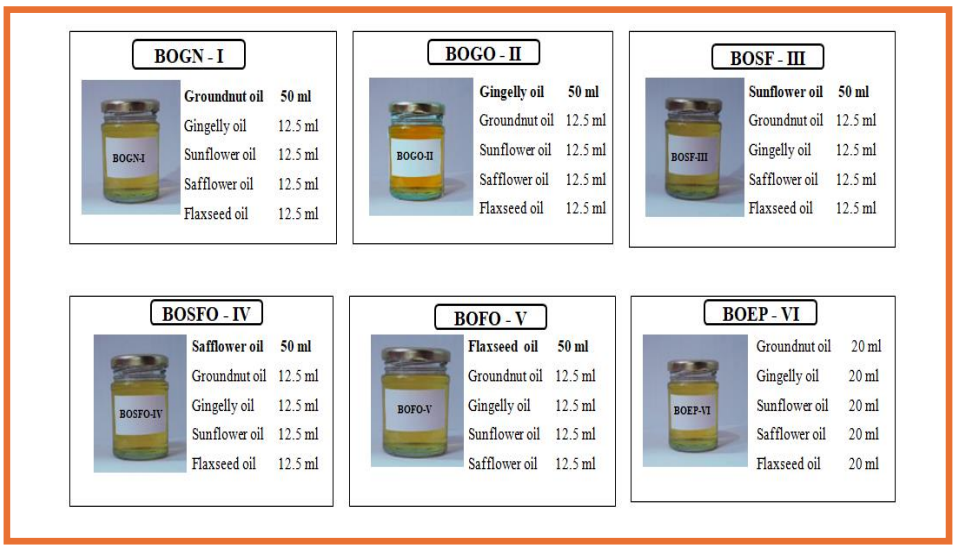

Plate 1: Formulation of Blended Vegetable Oil

The formulated oils for blending were taken in a conical flask and shaken for 90 rpm using an orbital shaker at 37^0 C for 24 hours and were kept in the sonicator for 15 mins and transferred to an airtight container.

Sensory analysis

All six blended vegetable oils were tested for their acceptability in terms of colour, flavour, texture, taste, and appearance using a nine-point hedonic scale by a

panel of 20 semi-trained panel members. Based on the overall score they were rated as highly acceptable (35-45), acceptable (25-35), and not acceptable (less than 25).

Analysis of physical properties

The physical properties of all the six formulated blended vegetable oil for colour (Gowegroup ultitester colour card reader), refractive index (Abbes Refractometer at a thermo stable environment $\pm 0.1^0$ C at a wavelength of 89.3nm - AOAC 17th ed. 2001), density (AOAC 185.19), viscosity (Viscometer at 27^0 C of temperature), smoking temperature (Thermometer (Thermopro), solubility (tested in water, ethanol, chloroform and petroleum ether) were analyzed using standard procedure.

Analysis Chemical Properties

To test the chemical properties, the peroxide level- (titration method AOAC-965.33), iodine value (Wijs method AOAC-920.159), saponification value (AOAC-920.160), acid value (AOAC-940.28), free fatty acids (AOAC-940.28), tocopherol content - (High-Performance Liquid chromatography with UV detector -AOAC-2012.09) of all the six formulated blended vegetable oils were analyzed using standard procedure.

Phase III: Fatty Acids Profile of Formulated Blended Vegetable Oils

Quantitative analysis for the fatty acids profile of all six blended vegetable oils was carried out using the Gas Chromatography – Flame Ionization detection method (AOAC 996.06) – AOAC, 2019.

Phase IV: Fatty Acids Profile of Selected Recipes Cooked using Formulated Blended Vegetable Oil

Preparation of recipes with blended vegetable oil: To understand the fatty acid profile of foods cooked using the formulated blended vegetable oils, three commonly consumed recipes namely vadai (deep fat frying), chapatti (pan frying), and potato poriyal (sautéing) were selected. The above recipes were standardized and were cooked using the formulated blended vegetable oils and were compared with the same recipes cooked in commonly consumed oils namely groundnut, gingelly, and sunflower oils. Fat from cooked products was extracted (Soxhlet extraction) and the fatty acid profile of the absorbed fat was analyzed (GC-FID) (AOAC 996.06) – AOAC, 2019.

The Institutional Human Ethics Clearance was obtained (AUW/IHEC/FSMD-19-20/XPD-28).

Results

Phase I: A Survey on Consumption of Fats and Oils and Market Availability of Blended Oils

A) Survey on Household Consumption of Fats and Oils

- The age of the selected female respondents was between 25 and 55 years.
- Fifty-three percent of the respondents were found to have completed their undergraduate level of education.
- The monthly income of 37% of households ranged between Rs.18, 953 to 31,590.
- Out of 196 households, 48% of households belonged to upper lower socio-economic status. None of the selected households belonged to the upper class.
- Consumption of groundnut oil was found to be maximum (108 ml/d), followed by sunflower oil (87 ml/d). However, palm oil consumption was seen in 50 households.
- The quantum of monthly purchase of oil was found to be high in upper-middle income and lower-middle income class. Also a higher quantum of consumption of palm oil among lower-income households was observed.
- Per day consumption of groundnut oil (80 ml/d) and gingelly oil (6 ml/d) was found to be low among the lower income group, at the same time weekly consumption of palm oil (375 ml) was found to be high in the lower income group.

B) Market Survey on Availability of Blended Vegetable Oils

- The number of brands available for groundnut oil was more (8) followed by gingelly (5) and coconut oil (4).
- A total of eight brands of blended vegetable oils were available in the market, out of which seven brands were blended with only two oils, and only one brand was blended with three oils. Blending with more than three oils was not

observed. Five out of eight brands used rice bran oil for blending, since it is the richest source of vitamin E.

Phase II: Formulation of Blended Vegetable Oils and their Quality Analysis

- The refractive index of blended vegetable oils ranged between 1.45 and 1.46. No significant difference between the six blended oils and stand-alone oils was observed.
- The density of blended vegetable oils ranged between 0.92 g/ml and 0.98 g/ml. The BOSFO-IV (0.92 ± 0.11g/ml) with 50 ml of safflower oil had a lower density than other blended vegetable oils.
- On the whole the viscosity of all the formulated blended oil ranged between 48.67 ± 1.15 to 69.53 ± 9.81. The viscosity of blended oil BOFO-V (52.00±1.73) and BOEP-VI (53.00 ± 1.73) was reported to be similar indicating a uniform thermal behavior while heating.
- All the stand-alone oil and formulated blended vegetable oils were observed to be soluble in water, chloroform, petroleum ether and ethanol.
- The smoking temperature of blended vegetable oils ranged between 157^0 C and 194.4^0 C. The lowest smoking temperature was observed for BOFO-V (157^0C) with 50 ml of flaxseed oil and 12.5 ml each of groundnut, gingelly, sunflower and safflower oil and the highest smoking temperature was observed for BOGN-I (194.4^0 C) with 50 ml of groundnut oil and 12.5 ml each of gingelly, sunflower, safflower and flaxseed oil.
- All six blended oils were tasteless, and the BOFO-V with the 50 ml of flaxseed oil and 12.5 ml each of groundnut, gingelly, sunflower and safflower oil had a fish odor which intensified while heating. The texture of all blended vegetable oils was light and non greasy.
- The colour of the BOGN-I and BOSFO-IV was found to be dark yellow and BOSF-III and BOFO-V were found to be light yellow.
- On the whole the peroxide value of all the formulated blended oil was observed to be more or less similar with the values ranging between 0.003±0.05Meq/kg to 0.06 ±0.05 Meq/kg). A significance difference in the peroxide value between the blended vegetable oil and stand alone oil was observed at 1% level of significance indicating a better oxidative stability.

- The iodine value of stand-alone oils ranged between 84mgKOH/g and 150mgKOH/g. The highest iodine value was observed for safflower oil (150.33±0.58 mg KOH/g). A significant increase in iodine value was observed between the formulated blended vegetable oils and stand-alone oils at a one percent level of significance.
- The saponification value of blended vegetable oil ranged between (190.67±0.58 mg/KOH to 261.67±0.58 mg/KOH).
- The acid value of blended vegetable oil ranged between 1.36±0.00 and 2.21±2.02mgKOH/g. The lowest acid value was reported in BOFO-V (1.36±0.00 mgKOH/g), followed by BOSFO-IV (1.92±0.017 mgKOH/g).
- The free fatty acid level of blended vegetable oil at 1% level of significance except for BOEP-VI with an equal proportion of groundnut (1.02±0.00%), gingelly oil (5.52±0.00%), sunflower oil (0.33±0.00), safflower oil (0.33±0.00) and flaxseed oil (0.74±0.00) was observed.
- The alpha-tocopherol content of BOSF- III (36.80mg/g) was higher, followed by BOSFO-IV (32.93mg/g) and BOGN-I (23.53mg/g). The least alpha-tocopherol content was observed in BOFO- V (2.80mg/g).
- In general, the overall acceptability level of the formulated blended vegetable oils was on par with the acceptability levels of the stand-alone oils.
- Also, out of the six formulations, BOFO-V comparatively obtained the lowest acceptability score (37.50±0.23), which can be attributed to a distinct fish odor during deep fat frying.
- No significant difference in the overall acceptability score was observed at 1% level of significance for pan frying for BOGN-I (37.62±0.5) and BOGO-II (38.08±0.075), with that of the stand-alone oil namely groundnut oil (37.34±0.24), gingelly (37.32±0.26), sunflower oil (37.44±0.42).

Phase III: Fatty Acid Profile of Blended Vegetable Oils

- The level of saturated fats in formulated blended vegetable oils ranged between 14.3g to 40g. The highest amount of saturated fat was found in BOSFO-VI (40g) and the least in BOGO-II (14.35g) reported the highest percentage of PUFA, BOGN-II (59g) reported the lowest percentage of PUFA BOGN-I (31g).

- The presence of methyl linolate a n-6 fatty acids was found to be high in BOSF-III (59.299%) and BOSFO-IV (55.812%). Also, the presence of methyl eicosenate a MUFA was found to be high in BOFO-V (22.450%) compared to stand-alone oil (groundnut oil- 0.702%, gingelly oil- 0.239%, sunflower oil- 0.150%, flaxseed oil - 0.703%).

Phase IV: Fatty Acids Profile of Cooked Products using Blended Vegetable Oils

- For deep fat frying (Vadai), although the percentage of oil absorption of BOGN-I (24.20g) was similar to that of groundnut oil (24.83g), the quantum of absorption of saturated fatty acids was less (4.57g) than the groundnut oil (6.50g).Similarly the quantum of absorption of polyunsaturated fatty acids was found to be greater (10.02g) than groundnut oil (7.44g).
- For deep fat frying (vadai), compared to groundnut oil (29.649%), the presence of methyl linolate was found to be high in all the blended vegetable oils. The percentage of peak areas of BOSF-III (49.714%) for methyl linolate was found to be similar to that of sunflower oil (49.234%). BOGO-II (22.450%) reported a higher percentage of peak area for methyl eicosenate. Also the blended vegetable oils BOSFO-IV (1.29g) and BOGN-II (1.46g) reported a lesser percentage of saturated fats.
- For pan frying (Chapatti), the oil absorption of blended vegetable oils ranged between 4.08g to 12.56g. The least oil absorption was noted in BOSF-III (4.08g), followed by BOSFO-IV (5.15g) and BOFO-V (5.77g). The highest absorption was noted in BOEP–VI (12.56g). BOSF-III reported the least PUFA (1.21g) content. The percentage of trans fat was found to be <0.1g in all blended and stand-alone oils.
- For pan frying (Chapatti), all the six blended oils in this study reported a lesser percentage of peak area for all the saturated fat. Though methyl oleate was found to be higher in BOSF-III (45.147%) followed BOEP-VI (39.733), it was found to be lesser compared to all stand- alone oils.
- For sautéing (potato poriyal), the oil absorption of blended vegetable oils ranged between 4.72g to 26.33g. The least oil absorption was noted in BOGN-I (4.72g), followed by BOGO-II (5.61g) and BOFO-V (8.76g). The highest absorption was noted in BOSFO–IV (26.33g). BOGN-I reported the least PUFA (1.94g)

content. The percentage of trans fat was found to be <0.1g in all blended and stand-alone oils.

- For sautéing (potato poriyal), the presence of methyl linolate was found to be higher in BOSFO-IV (55.812%) followed by BOSF-III (47.860%) compared to gingelly oil (37.983%) and groundnut oil (34.151%).
- The shelf life of formulated blended vegetable oil (BOGN-II) without antioxidant reported 49 days of shelf life.
- The shelf life of formulated blended vegetable oil with antioxidants also reported 35-50 days of shelf life in general blended oil BOFO-II reported maximum shelf life of 49 days.

Conclusion

- The chemical properties of the blended vegetable oils reported better oxidative stability compared to stand-alone oils.
- The sensory attributes of all the blended vegetable oils were in par with the stand-alone oils and hence can serve as an alternate cooking medium.
- The BOSF-III and BOSFO-IV were found to be superior in physical and chemical properties.
- Also, the above two blends reported the least oil absorption in cooked products and were found to be low in saturated fats, and high in MUFA and PUFA. Hence it can be recommended as healthier oils compared to stand-alone oils.

Limitations

- Due to COVID pandemic, only 196 households were surveyed.
- Financial constraints limited the ability to explore fatty acid contents of more commonly consumed recipes under different types of frying.
- Optimizing the blended oils to meet the desirable ratio of 1:1.3:1 of SFA: MUFA: PUFA was not possible due to constraint of time.

Recommendations

- Oil absorption studies using blended vegetable oils for various commonly consumed snacks and savories can be taken up in the future.
- As a follow-up study optimization of the blended vegetable oil for desirable SFA, PUFA, and MUFA (1:1.3:1) ratio can be taken up in future.

- In vivo study to investigate the digestibility and absorption of blended oils providing valuable insights into their bioavailability and nutritional efficacy.

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